ORIGINAL ARTICLE

Mandibular canine dimensions as an aid in gender estimation

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Abstract

Background: All humans have an identity in life; compassionate societies require this identity to be recognized even after death. **Objectives:** To measure the dimensions of the mandibular canine and assess the usefulness of the mandibular canine as an aid in gender estimation. **Materials and Methods:** The study population comprised 200 subjects inclusive of 100 males and 100 females with an age range of 18–25 years. Measurements made in mm at the contact point were of mesiodistal width of the right and left canines and intercanine distance both intraorally and on casts, and the mandibular canine index (MCI) was calculated. The obtained data were subjected to *t*-test/Mann-Whitney test and discriminant function analysis. **Results:** All parameters of mandibular canines, namely, intercanine distance, canine width, and canine index were greater in males compared to females suggesting significant sexual dimorphism of mandibular canines. On subjecting the data to discriminant function analysis, it classified sex correctly in 73% of the samples. **Conclusion:** The result of our study establishes the existence of significant sexual dimorphism in mandibular canines. We can therefore, recommend the use of mandibular canine dimensions as an applicable and additional method for gender determination in human identification.

Key words: Gender estimation, mandibular canine, mandibular canine index

Introduction

All humans have an identity in life; compassionate societies require this identity to be recognized even after death.[1] Sex assessment of skeletal remains is an important step in building the biological profile of unidentified skeletons and it is widely agreed that the skull and pelvis are the most useful skeletal regions for sex determination.[2,3] The only method that can give a totally accurate result is the DNA technique but in many cases it cannot be used.

Teeth are good material in living and nonliving populations for anthropological, genetic, odontological, and forensic investigations. The morphological differences of the teeth between males and females have been reported and can be applied to identify the gender from dental remains.[4] Canines have consistently shown the greatest sexual dimorphism; moreover, they are robust in terms of resistance to disease and trauma and more likely to remain intact in postmortem scenarios.[5]

Dental indices are shown to have evolutionary, developmental, and clinical significance. However, their use in forensic sex identification has not been explored fully.[6]

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With this background, this study was undertaken to measure mandibular canine dimensions and intercanine distance and calculate the mandibular canine index (MCI) in order to assess their usefulness in the estimation of gender.

Objectives

The present study was designed with the following objectives:

- To measure mesiodistal width of the right mandibular canine
- To measure mesiodistal width of the left mandibular canine
- To measure intercanine distance
- To calculate the MCI
- To assess usefulness of the mandibular canine as an aid in gender estimation.

Materials and Methods

The study was conducted in Mathrusri Ramabai (M.R.) Ambedkar Dental College and Hospital, Bangalore, Karnataka, India on 200 subjects, inclusive of 100 males and 100 females in the age group of 18–25 years, who were randomly selected after obtaining their informed consent. The present study was approved by the ethical review board of M.R. Ambedkar Dental College and Hospital, Bangalore, Karnataka, India. A detailed case history was recorded to ensure the selection of ideal subjects. The subjects with the following criteria were included in the study:

- Subjects with a healthy state of gingiva and periodontium
- Subjects with mandibular canines free from dental caries
- Subjects with normal overjet and overbite of teeth (2–3 mm)
- Subjects with an absence of spacing in the anterior teeth
- Subjects with Angle's Class 1 molar and canine relationship.

The exclusion criteria employed for the selection of subjects was the presence of partially erupted or ectopically erupted teeth and missing teeth, subjects with dental or occlusal abnormalities such as rotation, crowding, and occlusal disharmony, teeth showing physiologic or pathologic wear and tear (e.g., attrition, abrasion, abfraction, and erosion), subjects with deleterious habits such as bruxism, subjects with developmental anomalies of teeth, subjects with history of trauma and orthodontic treatment.

Measurements were made intraorally and later on, the casts obtained from the same subjects using digital vernier caliper (Mitutoyo-Headquaters, Takatsu-Ku, kawasaki, kanagawa, Japan; resolution: 0.01 mm; accuracy: ±0.02 mm). Alginate impressions of the mandibular arches were taken using metallic perforated impression trays and the resultant impressions were thoroughly cleaned and disinfected. Type III dental stone was used to make study models from the alginate impressions, which were used for conducting the measurements after complete setting.

The following measurements, as listed below, were taken both intraorally and on the study models of the subjects:

- Right mandibular canine width: Measured as the greatest mesiodistal dimension of the right mandibular canine
- Left mandibular canine width: Measured as the greatest mesiodistal dimension of the left mandibular canine.
- Intercanine width: Measured linear from the cusp tip of the right mandibular canine to the cusp tip of the left mandibular canine
    - The observed MCI was calculated using the following formula

$$MCI = \frac{\text{Mesiodistal width of the mandibular canine}}{\text{Intercanine distance}}$$

Sexual dimorphism in the right and left mandibular canines was calculated using the formula given by Garn and Lewis (1967), which is as follows:

Sexual dimorphism = Xm − 1 × 100 / Xf

Where Xm = mean canine width of males and Xf = mean canine width of females

The measurements obtained were subjected to *t*-test/Mann-Whitney test and discriminant functional analysis.

Results

The data were collected, tabulated, and subjected to statistical analysis. The results are as follows [Tables 1-8]:

Two parameters, namely, right canine width and left canine index in casts of both males and females failed the tolerance test due to high fluctuation. So, they have not been included in the final discriminant model.

Using Fisher's linear discriminant function [Tables 4-7], the coefficient of each parameter was determined. In males (50%), intercanine distance-intraoral (X1) was 1876.94, intercanine distance-casts (X2) was 6.08, right canine width-intraoral (X3) was -4585.10, left canine width-intraoral (X4) was -2843.31, left canine width-cast (X5) was 40.23, right canine index-intraoral (X6) was -385.38, right canine index-cast (X7) was 120666.72, and left canine index-intraoral (X8) was 71058.19.

In females (50%), intercanine distance-intraoral (X1) was 1877.68, intercanine distance-casts (X2) was 6.23, right canine width-intraoral (X3) was -4588.68, left canine width-intraoral (X4) was -2845.50, left canine width-cast

Table 1: Comparison of different parameters between males and females

Parameter	Group	Gender	Mean	Standard deviation	SE of mean	Mean difference	t/z	*P*
Intercanine distance†	Intraoral	Male	26.36	1.56	0.16	0.894	−3.929	<0.001*
		Female	25.46	1.69	0.17			
	Casts	Male	26.18	2.52	0.25	0.711	−3.823	<0.001*
		Female	25.47	1.69	0.17			
Right canine width	Intraoral	Male	6.81	0.41	0.04	0.435	7.456	<0.001*
		Female	6.37	0.41	0.04			
	Casts	Male	6.81	0.41	0.04	0.433	7.427	<0.001*
		Female	6.37	0.41	0.04			
Left canine width	Intraoral	Male	6.91	0.40	0.04	0.447	7.940	<0.001*
		Female	6.46	0.39	0.04			
	Casts	Male	6.91	0.40	0.04	0.517	6.201	<0.001*
		Female	6.39	0.73	0.07			
Right canine index†	Intraoral	Male	0.26	0.01	0.00	0.007	−3.618	<0.001*
		Female	0.25	0.02	0.00			
	Casts	Male	0.26	0.01	0.00	0.008	−3.665	<0.001*
		Female	0.25	0.01	0.00			
Left canine index†	Intraoral	Male	0.26	0.02	0.00	0.008	−3.661	<0.001*
		Female	0.25	0.01	0.00			
	Casts	Male	0.26	0.02	0.00	0.008	−3.673	<0.001*
		Female	0.25	0.01	0.00			

†Mann-Whitney test, *Denotes significant difference. SE: Standard error, t/z: *t*-test/Mann-Whitney test

Table 2: Comparison of different parameters within males between intraoral and casts

Parameter	Group	Mean	Standard deviation	SE of mean	Mean difference	t/z	*P*
Intercanine distance†	Intraoral	26.36	1.56	0.16	0.182	−0.038	0.970
	Casts	26.18	2.52	0.25			
Right canine width	Intraoral	6.81	0.41	0.04	0.001	0.021	0.984
	Casts	6.81	0.41	0.04			
Left canine width	Intraoral	6.91	0.40	0.04	−0.006	−0.109	0.904
	Casts	6.91	0.40	0.04			
Right canine index†	Intraoral	0.26	0.01	0.00	0.000	−0.028	0.978
	Casts	0.26	0.01	0.00			
Left canine index†	Intraoral	0.26	0.02	0.00	0.000	−0.004	0.997
	Casts	0.26	0.02	0.00			

†Mann-Whitney test. SE: Standard error, t/z: *t*-test/Mann-Whitney test

Table 3: Comparison of different parameters within females between intraoral and casts

Parameter	Group	Mean	Standard deviation	SE of mean	Mean difference	t/z	*P*
Intercanine distance†	Intraoral	25.46	1.69	0.17	−0.002	−0.016	0.987
	Casts	25.47	1.69	0.17			
Right canine width	Intraoral	6.37	0.41	0.04	−0.001	−0.021	0.984
	Casts	6.37	0.41	0.04			
Left canine width	Intraoral	6.46	0.39	0.04	0.064	0.776	0.439
	Casts	6.39	0.73	0.07			
Right canine index†	Intraoral	0.25	0.02	0.00	0.001	−0.038	0.970
	Casts	0.25	0.01	0.00			
Left canine index†	Intraoral	0.25	0.01	0.00	0.000	−0.029	0.977
	Casts	0.25	0.01	0.00			

†Mann-Whitney test. SE: Standard error, t/z: *t*-test/Mann-Whitney test

(X5) was 39.77, right canine index-intraoral (X6) was -372.97, right canine index-cast (X7) was 120743.66, and left canine index-intraoral (X8) was 71047.75

The equations thus formed are:

M = C + (1876.94)*X1 + (6.08)*X2 - (4585.10)*X3 - (2843.31)*X4 + (40.23)*X5 - (385.38)*X6 + (120666.72)*X7 + (71058.19)*X8

Table 4: Descriptive statistics for different parameters

Parameter	Male		Female		Total	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Intercanine distance-intraoral	26.36	1.56	25.46	1.69	25.91	1.68
Intercanine distance-casts	26.18	2.52	25.47	1.69	25.82	2.17
Right canine width-intraoral	6.81	0.41	6.37	0.41	6.59	0.47
Right canine width-casts	6.81	0.41	6.37	0.41	6.59	0.46
Left canine width-intraoral	6.91	0.40	6.46	0.39	6.68	0.46
Left canine width-casts	6.91	0.40	6.39	0.73	6.65	0.64
Right canine index-intraoral	0.26	0.01	0.25	0.02	0.25	0.02
Right canine index-casts	0.26	0.01	0.25	0.01	0.25	0.01
Left canine index-intraoral	0.26	0.02	0.25	0.01	0.26	0.01
Left canine index-casts	0.26	0.02	0.25	0.01	0.26	0.01

Table 5: Identification of significant factors (parameters) in determining gender using discriminant analysis

Parameter	Wilks' λ	F	*P*
Intercanine distance-intraoral	0.929	15.108	<0.001*
Intercanine distance-casts	0.973	5.490	0.020*
Right canine width-intraoral	0.781	55.598	<0.001*
Right canine width-casts	0.782	55.161	<0.001*
Left canine width-intraoral	0.759	63.037	<0.001*
Left canine width-casts	0.837	38.456	<0.001*
Right canine index-intraoral	0.955	9.362	0.003*
Right canine index-casts	0.927	15.663	<0.001*
Left canine index-intraoral	0.922	16.709	<0.001*
Left canine index-casts	0.922	16.735	<0.001*

*Denotes a significant factor

Table 6: Tolerance test result

Variables failing tolerance test	Variance within groups	Tolerance	Minimum tolerance
Right canine width-casts	0.16955	0.00028	0.00028
Left canine index-casts	0.00021	0.00048	0.00045

Table 7: Classification function coefficient: Using Fisher's linear discriminant function

Parameter	Male	Female
Constant (C)	−24363.20	−24364.99
Intercanine distance-intraoral (X_1)	1876.94	1877.68
Intercanine distance-casts (X_2)	6.08	6.23
Right canine width-intraoral (X_3)	−4585.10	−4588.68
Left canine width-intraoral (X_4)	−2843.31	−2845.50
Left canine width-casts (X_5)	40.23	39.77
Right canine index-intraoral (X_6)	−385.38	−372.97
Right canine index-casts (X_7)	120666.72	120743.66
Left canine index-intraoral (X_8)	71058.19	71047.75

Table 8: Classification results

Actual gender	Predicted gender		Correctly classified (%)
	Male	Female	
Male	68	32	73
Female	22	78	

F = C + (1877.68)*X1 + (6.23)*X2 - (4588.68)*X3 - (2845.50)*X4 + (39.77)*X5 - (372.97)*X6 + (120743.66)*X7 + (71047.75)*X8

A given sample would get classified into one of the groups based on the maximum value that is recorded when the value of each parameter for that sample is substituted in both the equations above. It was inferred that right canine index-cast is strongly significant among all parameters followed by left canine index-intraoral, right canine width-intraoral, left canine width-intraoral, intercanine distance-intraoral, right canine index-intraoral, left canine width-casts, and intercanine distance-casts in the decreasing order.

On application of discriminant function analysis [Table 8], in an actual 100-male sample size it predicted 68 samples as males and 32 samples as females. In an actual 100-female sample size, it predicted 78 samples as females and 22 samples as males. On an average, in a sample size of 200 comprising 100 males and 100 females, the discriminant model could correctly classify 73% of the samples.

Discussion

The estimation of sex is an important concern of the osteologist and the forensic anthropologist as it is critical for individual identification.[7] Being the hardest and chemically the most stable tissues in the body, teeth are selectively preserved and fossilized, thereby providing by far the best record for evolutionary change.[8]

The study was performed on 200 subjects comprising 100 males and 100 females in the age group of 18–25 years. The rationale behind selection of the said age group was that this group comprised individuals in whom all permanent canines had fully erupted and in whom attrition was minimal.[9]

In our study, out of 200 subjects, 100 were males and 100 were females [Table 1]. Sexual dimorphism in canine size is influenced markedly by genetic factors. Both X and

Y chromosomal involvement has been found by various workers.[10] Amelogenesis is a sex-linked process and provides the basis for odontometric sexual dimorphism and so the means to estimate sex solely by the dentition. Approximately 90% of the genetic coding for ameloglobin (the organic component, which constitutes 90% of the enamel) is located on the X chromosome with the remaining 10% on the Y chromosome in males. The physiological manifestation of this coding is that males undergo a lengthier period of enamel formation than females, approximately 80 days or 0.56 mm diametrically in permanent canines according to some sources.[11]

In the present study, measurements made intraorally and on the casts did not differ and were statistically insignificant [Tables 2 and 3]. This revealed that both intraoral and cast measurements were similar and accurate. It was consistent with Kaushal *et al*.[8] but Barrett *et al*.[11] have observed that intraoral measurements are less reliable.

In a study, the accuracy of measurements of tooth dimensions on dental casts had been investigated and it was found that dental casts facilitated the analysis of tooth size, shape, alignment, rotations of the teeth, presence or absence of teeth, arch width, length, form, symmetry, and occlusal relationship with a high degree of accuracy.[4]

In the present study, measurements were made mesiodistally at the contact point for obtaining the mandibular right canine width and left canine width. Various studies found the measurements of mesiodistal width at contact point to be accurate. But in a study conducted by Johanna Morgan[12] to overcome the limitations of measuring mesiodistal width at contact point of the mandibular canine such as interstitial wear, measurements were made at the cervical buccolingual and mesiodistal. Sexual dimorphism was statistically insignificant and no sexual dimorphism was considered to exist in the cervical region.

The *t*-test/Mann-Whitney test was applied to compare the different parameters between males and females. In our study, intercanine distance, the mandibular right and left canine width were greater in males compared with females and statistically significant. But in a study conducted by N. Vishwakarma and Guha *et al*.,[10] intercanine distance was statistically insignificant.

In the present study, the mandibular canine width values were greater in males compared with females and were statistically significant. But the reverse dimorphism was observed in a study conducted by Karen Boaz *et al*.[9] in the South Indian population where mesiodistal and buccolingual dimensions were considered.

In our study, measurements of the left mandibular canine width was greater compared to the right mandibular canine width in both males and females. This difference was in agreement with studies conducted by Karen Boaz *et al*.,[9] Garn *et al*.,[13] and Krishnamurthy Anuthama *et al*.[14] in permanent mandibular canines. But Hashim and Murshid *et al*.,[15] Vandana M. Reddy *et al*.,[16] Aliaa Omar *et al*.,[4] and Darah Parekh *et al*.[17] found no statistical difference between the right and left canine width.

In the present study, the left mandibular canine showed a greater sexual dimorphism (6.96%) when compared to the right mandibular canine (6.90%). This finding was in consistence with studies conducted by Rishab Kapila *et al*.[18] and Kaushal *et al*.[8]

Laterality is now recognized as an intrinsic characteristic of living organisms. Dental asymmetry in the Neanderthals tends to be greater than in modern man. Harper provides evidence that the right-left differences between homologous teeth are smaller than the differences between the teeth of monozygotic twins, suggesting that the side differences can be attributed to environmental influences. According to Garn, intraindividual variations in crown size and similarities between isomers and antimeres might be derived from specific intrauterine events during odontogenesis and less from genetic effects.[19]

In our study, the right MCI and left MCI were greater in males compared with females and statistically significant. We found the MCI relevant in determining sexual dimorphism of mandibular canines. This finding was consistent with studies conducted by Kaushal *et al*.,[8] Vandana M. Reddy *et al*.,[16] and Irfan Ahmed Mughal *et al*.[20] Muller *et al*.[21] conducted a study and concluded that when mandibular anterior teeth alignment is not correct, gender determination is not possible using MCI.

We found the right canine index-casts to be strongly significant among all parameters. Ashith B Acharya *et al*.,[22] who conducted a study on the Nepalese population to validate MCI as a sex predictor found contrasting results. Their results suggest that MCI has little reliability in sex assessment and its application should be restricted. Their explanation is that the MCI is a relative value obtained as the ratio of two absolute measurements [mesiodistal (MD) dimension of canines and intercanine arch width], and does not reflect sex differences that exist in absolute measurements *per se*.

There are certain shortcomings in using dental morphometrics for gender determination. Human dental sexual dimorphism was greater during the Upper Paleolithic era than at any subsequent time and it has almost vanished in some modern human populations, a phenomenon that seems to be related to gracilization of the males.[23] The magnitude and pattern of sexual dimorphism in the size of teeth differ from one population to another.[15]

Population variation is most apparent when distinct ethnic groups are compared (Europeans and Asians for example) but accuracy can vary significantly even within somewhat related groups.[11]

The canines are favored as ideal teeth to study the differences in view of their durability in the oral cavity. They were found to have greater resistance to periodontal diseases and severe trauma. This is attributed to their long roots, which are firmly anchored in the alveolar bone and the labiolingual thickness of the crown and root, which enables them to sustain stress and trauma. In addition, the crown portions of the canines are shaped in a manner that promotes self-cleansing, thus giving them greater resistance to periodontal diseases. These characteristics of canine teeth tend to preserve them throughout life; therefore, the canines are usually the last teeth to be lost.[4] The canines exhibit the greatest divergence that is likely due to their function: They are designed for puncturing and tearing and so are most efficient in both meat consumption and inflicting damage in competition.[11]

Metric methods of gender estimation possess several benefits relative to their morphological counterparts as they are considered objective because they rely on standard landmarks. They also result in a lower incidence of errors.[4]

In the present study, intraoral and cast measurements of mandibular canines were exact and equally good. So, either of these can be used for calculations. All the parameters of mandibular canines, namely. intercanine distance, canine width, and canine index were greater in males compared with females suggesting significant sexual dimorphism of mandibular canines. The left mandibular canine width was greater compared with the right mandibular canine width in both males and females suggesting the left mandibular canine to be more sexually dimorphic. On subjecting the data to discriminant function analysis, the right mandibular index casts were strongly significant among all the parameters. From the results of our study we found that the mandibular canine dimensions were able to correctly classify sex in up to 73% of the cases. Earlier studies conducted by Rao *et al*.,[24] Irfan Ahmed Mughal *et al*.,[20] and Vandana M. Reddy *et al*.[16] could detect sex correctly in 85.9%, 75.97%, and 70% of the cases, respectively.

This method is relatively simple, time-saving, and economical. Mandibular canine dimensions can be useful to corroborate the gender of human remains with a high degree of certainty, especially in cases of major catastrophes when bodies are often damaged beyond recognition. Since tooth morphology is population-specific and known to be influenced by cultural, environmental, and racial factors, it is necessary for further studies of various races to be conducted so as to have dental morphometric standards set to enable gender differentiation in human identification.

Conclusion

In conclusion, it is of prime importance to estimate the gender of unknown skeletal remains. There exists an increased challenge when a human body in its entirety is not available and it is incumbent that forensic experts exhaust faster and simpler procedures to establish at least the gender of such remains. The urgency for such an expedient method is imperative as we live in an age where explosive devices are in rampant use. These methods of extermination often leave the victims' remains strewn and scattered affording forensic teams very little to work with. The result of our study establishes the existence of significant sexual dimorphism in mandibular canines. We can therefore, recommend the use of mandibular canine dimensions as an applicable and additional method for gender estimation in human identification.

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Conflicts of interest

There are no conflicts of interest.

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